

An Introduction to Comets

(courtesy of Bill Arnett)

Unlike the other small bodies in the solar system, comets have been known since antiquity. There are Chinese records of Comet Halley going back to at least 240 BC. The famous Bayeux Tapestry, which commemorates the Norman Conquest of England in 1066, depicts an apparition of Comet Halley.

As of 1995, 878 comets have been cataloged and their orbits at least roughly calculated. Of these 184 are periodic comets (orbital periods less than 200 years); some of the remainder are no doubt periodic as well, but their orbits have not been determined with sufficient accuracy to tell for sure.

Comets are sometimes called dirty snowballs or "icy mudballs". They are a mixture of ices (both water and frozen gases) and dust that for some reason didn't get incorporated into planets when the solar system was formed. This makes them very interesting as samples of the early history of the solar system.

When they are near the Sun and active, comets have several distinct parts:

nucleus: relatively solid and stable, mostly ice and gas with a small amount of dust and other solids;

coma: dense cloud of water, carbon dioxide and other neutral gases sublimed from the nucleus;

hydrogen cloud: huge (millions of km in diameter) but very sparse envelope of neutral hydrogen;

dust tail: up to 10 million km long composed of smoke-sized dust particles driven off the nucleus by escaping gases; this is the most prominent part of a comet to the unaided eye;

ion tail: as much as several hundred million km long composed of plasma and laced with rays and streamers caused by interactions with the solar wind.

Comets are invisible except when they are near the Sun. Most comets have highly eccentric orbits which take them far beyond the orbit of Pluto; these are seen once and then disappear for millennia. Only the short- and intermediate-period comets (like Comet Halley), stay within the orbit of Pluto for a significant fraction of their orbits.

After 500 or so passes near the Sun off most of a comet's ice and gas is lost leaving a rocky object very much like an asteroid in appearance.

(Perhaps half of the near-Earth asteroids may be "dead" comets.) A comet whose orbit takes it near the Sun is also likely to either impact one of the planets or the Sun or to be ejected out of the solar system by a close encounter (esp. with Jupiter).

By far the most famous comet is Comet Halley but SL 9 was a "big hit" for a week in the summer of 1994.

Meteor shower sometimes occur when the Earth passes thru the orbit of a comet. Some occur with great regularity: the Perseid meteor shower occurs every year between August 9 and 13 when the Earth passes thru the orbit of Comet Swift-Tuttle. Comet Halley is the source of the Orionid ,shower in October.

Many comets are first discovered by amateur astronomers. Since comets are brightest when near the Sun, they are usually visible only at sunrise or sunset. Charts showing the positions in the sky of some comets can be created with a planetarium program such as Starry Night.

Comet Definitions

(courtesy of C. Morris, <http://encke.jpl.nasa.gov/>)

The following are generally accepted definitions for terms related to cometary astronomy.

absolute magnitude (H₀)

The brightness of a comet when it is at 1 AU from both the Earth and Sun. As this virtually never happens, this quantity is calculated from the comet's light curve. Unfortunately, this quantity is far from absolute. It can be different pre- and post-perihelion. It can also change from apparition to apparition (for periodic comets).

anti-tail or anomalous tail

When a comet's tail appears to be pointing toward the Sun, this is called an anti-tail or anomalous tail. In reality, the tail only appears to be pointing toward the Sun. To get an anti-tail, the comet must produce large ("heavy") dust particles. If this happens, these particles are left along the comet's orbit instead of being pushed away from the Sun and the comet's orbit by light pressure. Often dusty comets will produce particules of different sizes creating a fan-shaped appearance. The smallest dust will be pushed directly away from the Sun (like the gas tail) and the largest will be left in the comet's orbit. When a comet is close to the Sun, the angle of this fan can be 90 degrees or larger. If the Earth-comet-Sun geometry is correct, the dust in the comet's orbit will appear to point toward the Sun. [Try this...make a right (90 degree) angle with your thumb and index finger. Your index finger is the main tail and your thumb is the dust left in the comet's orbit. Point your finger and thumb directly away from you (keeping the angle 90

degrees). Your finger seems to be going in exactly the opposite direct from the thumb. This is what causes an anti-tail.]

apparition

The time during which a comet is under observation. For periodic comets which have more than one appearance, the term apparition is often used with the year of perihelion passage, such "the 1910 apparition of Comet Halley." The term probably is derived from the ghostly appearance of bright naked-eye comets.

astronomical unit (AU)

Standard unit for measuring distance within the solar system. One AU is equal to the average distance between the Sun and Earth or about 93 million miles.

coma or the comet's head

The comet's coma or head is the fuzzy haze that surrounds the comet's true nucleus. The coma (and tail) are really all that we see from Earth.

The shape of the coma can vary from comet to comet and for the same comet during its apparition. The shape depends on the comet's distance from the Sun and the relative amount of dust and gas production. For faint comets or bright comets producing little dust, the coma is usually round. Comets, which are producing significant quantities of dust, have a fan-shaped or parabolic comae. This is because different size dust is being released. The larger dust gets left along the comet's orbital path while smaller dust gets pushed away from the Sun by light pressure. The smaller the dust, the more directly away from the Sun the dust is pushed. With a distribution of both large and small dust sizes, a fan is created. For comets within 1 AU, the coma of a dusty comet often becomes parabolic in shape. Clearly, for comets with fan-shaped or parabolic comae, there is no obvious boundary between the coma and tail.

coma diameter

The diameter of the coma is usually given in minutes of arc ('). If the coma is round, this is a straightforward definition. If the coma is elongated or has a tail, the measurement represents the smallest dimension of the coma (usually at a right angle to the tail) and transecting the brightest part of the coma.

degree of condensation (DC)

DC is an indicator of how much the surface brightness of the coma increases toward the center of the coma. In general, DC=0 indicates totally diffuse and DC=9 means "stellar." As the DC increases, the coma size usually decreases and becomes more sharply defined. A totally diffuse

comet, with no brightening toward the center, is rated DC=0. With DC=3-5, there is a distinct brightening. By DC=7 you have a steep overall gradient and by DC=8 the coma is very small, dense, and intense with fairly well defined boundaries. With DC=9 the comet looks like a soft star or a planet in bad seeing.

geocentric distance (Δ)

The comet's distance from the Earth in astronomical units.

heliocentric distance (r)

The comet's distance from the Sun in astronomical units.

long-period comets

Comets with orbital periods greater than 200 years.

"n"

The photometric parameter n in the power-law formula for comet brightness, $m_1 = H_0 + 5 \log(\Delta) + 2.5n \log(r)$, indicates how fast the comet's brightness is changing with heliocentric distance, r . Specifically, n is the power in the power-law formula. That is, the comet's brightness varies as r to the $-n$ power. When the comet's heliocentric brightness, $m_1 - 5 \log(\Delta)$, is plotted against $\log(r)$, the slope of the straight line (assuming it is a straight line) is $2.5n$.

nucleus

The true nucleus of a comet has only been seen once (P/Halley by spacecraft). From the ground, the star-like nucleus always includes a cloud of dust and gas around the true nucleus. Hence, terms such as stellar condensation and nuclear condensation are often used when a star-like object is seen in the comet's coma. The magnitude of the "nucleus" is denoted m_2 and usually isn't of much use because one is really not such what m_2 represents. In general, the value of m_2 will get fainter as more magnification is applied.

observed magnitude (m_1)

The observed magnitude of the comet represents the integrated brightness of the comet's coma or head as seen from Earth. This is normally obtained by comparing the comet's average surface brightness with that of defocused stars (matching the comet's size) of known brightness. Because comets have size (in contrast to stars which are pinpoints of light), a comet of a given brightness will appear less obvious than a star of the same brightness.

opposition

The comet is in the midnight sky on the opposite side of the Earth from the Sun. A perfect opposition, which almost never happens, has the comet 180 degrees away from the Sun.

outburst (in brightness)

An unexpected increase in brightness over a short period of time due to the release of dust and gas into the coma from the nucleus. For a visual observer, the nuclear condensation (a bright spot near the center of the coma) will appear to become star-like and brighter in the comet's coma. Over time (hours - days), the size of the nuclear condensation will increase as the dust moves away from the nucleus. The change in brightness can be as little as half a magnitude and as much as many magnitudes.

perihelion

The point in a comet's orbit that it is closest to the Sun.

perihelion date

The date (and time) the comet reaches perihelion.

perihelion distance

The comet's distance from the Sun, usually expressed in Astronomical Units, at perihelion.

periodic or short-period comets

Any comet with an orbital period of less than 200 years. These comets are indicated by a "P/" before the names. For example, P/Halley is Halley's comet or more properly known as periodic Comet Halley. Recently, the International Astronomical Union has started numbering periodic comets that have been seen at more than one apparition. Thus, Halley's Comet is 1P/Halley and P/de Vico is now known as 122P/de Vico.

position angle (PA)

The PA of a tail or other cometary feature represents the direction on the sky (in degrees from north) toward which it is pointing. Thus, a comet in the morning sky (in the east) that has a tail pointing due west will have a PA of 270 degrees. A comet in with a tail pointing toward the south-east will have a PA of 135 degrees. It must be stressed that the determination of the PA of a tail (or other feature) requires plotting it on an atlas and measuring the angle with a protractor. PAs should be measured to at least five degree resolution. It is not possible to look

in an eyepiece and accurately estimate the PA of a tail. Also, the determination of PA in the polar regions of the sky is very tricky and may not be intuitive.

solar conjunction

The comet is near the Sun in the sky. Usually, this means that the comet will not be observable from Earth.

tail

The comet's tail is its most distinctive feature. Generally pointing away from the Sun, these appendages come in a variety of shapes and lengths. The lengths can vary from a small fraction of a degree (tails are always measured as the angular length either in degrees or minutes of arc [', 60' = one degree]) to the rare few that cover a significant fraction of the sky.

Visual Magnitude-Estimation Methods for Comets

(courtesy of D. Green, International Comet Quarterly)

Note that there are a few different acceptable methods for properly obtaining a total visual magnitude estimate of a comet, which is a much more difficult process than obtaining a visual magnitude estimate of a variable star (for example), due to the extended size of the comet's coma and to the combination of diffuse coma plus central condensation. All of the acceptable methods compare a comet's brightness with that of comparison stars from acceptable catalogues of V (or visual) magnitudes, or from atlases/charts that have such data inscribed next to star images. [It is not acceptable to produce magnitude estimates of comets based on comparison with "deep-sky" objects (nebulae, galaxies, star clusters) or on "observer experience".]

The three most commonly used extrafocal methods for determining the brightness of a comet are known as the VSS, VBM, and Modified-Out methods:

The VSS method, formerly known as the "In-Out method", is good for diffuse comets that do not have a strong central condensation; for this, you compare the memorized in-focus image of the comet to a de-focussed image of a comparison star (which is de-focussed to the same coma size as the in-focus comet). [This is often called the "Sidgwick" method, but predates Sidgwick by half a century via Vsekhsvyatskij, Steavenson, and others, and is now termed more historically-correct by the ICQ as the "Vsekhsvyatskij-Steavenson-Sidgwick" or "VSS" method.]

The standard, easy-to-use extrafocal VBM, or "Out-Out", method is only correct when the comet shows little coma (thus, mainly when comets are at small solar elongations and of mag 4 or brighter). With this method, which is sort of an "equal-out" extrafocal procedure (in that the comet and star are defocussed by the same amount), the observer slightly de-focusses both the comet and comparison star(s) the same amount (which makes this the easiest of the methods to use), until comet and star appear about the same size. [This has been called the "Bobrovnikoff" method, but predates Bobrovnikoff by many years via Van Biesbroeck and others, and is now termed more historically-correct by the ICQ as the "Van Biesbroeck-Bobrovnikoff-Meisel" or "VBM" method.]

However, the standard VBM method produces errant results for diffuse comets or comets with large coma sizes --- which is how comets usually appear! --- by giving magnitudes that are too faint, and should generally not be used.

Charles Morris' method is a "Modified Out" method that essentially combines the above "In-Out" and simple "Out-Out" methods into a single, better (though somewhat more difficult to use) extrafocal procedure --- in which the comet is defocused somewhat to smear out the nuclear condensation (and overall brightness gradient), making the defocused comet image as uniform as possible in surface brightness; the comparison stars are then (further) defocused to the same size as this defocused comet image, and one must make several observations of the memorized comet and star images for a good magnitude estimate. (In this method, the comet and star are usually defocussed by unequal amounts, yielding however a "more equally correct" surface brightness for the images of comet and star.)

The "Extrafocal-Extinction" method of Max Beyer, in which both comet and stars are defocussed excessively to see which disappears first, is not recommended for use.
